FASCIATIONS OF KNOWN CAUSATION

DR. HENRI HUS

Missouri Botanical Garden

Among plants, whether in the garden or in the field, individuals occur with greater or less frequency, which, because they exhibit a striking departure from the accustomed form, attract immediate attention. To denote such abnormal forms, the term "teratological" is used. Teratology covers a wide field. It includes the deviations from the usual arrangement of the parts, such as the union of organs and alterations of position, as well as deviations from the form, number and size of the parts of the plant. Frequently an explanation does not readily offer itself, at other times the inciting cause is demonstrated without trouble.

Though it is only in comparatively recent years that the true value of the study of abnormal forms has been realized, it must not be thought that in the earlier days the subject was overlooked. Numerous papers on teratological cases were published during the seventeenth century, for instance that by Wurffbain.[1] The eighteenth century saw an increase in the number of similar publications. Even Linnæus, before he enunciated his "varietates levissimas non curat botanicus," seems to have devoted some time to the study of abnormal forms.[2] At the same time, it was not until 1814 that the first collective publication on this subject, covering more than 300 pages and containing several illustrations, appeared.[3] This, at greater or lesser intervals, was followed by others, the

[1] Wurffbain, Johannes Paulus. De folia lactucæ monstroso. "Miscell. Acad. Nat. Curios.," Dec. 2, A. 10, 411, 1691.

[2] Linnæus, Carolus. Pommerantz med et inneslutit foster. "Vetensk. Akad. Handl.," A. 281, 1745.

[3] Jaeger, G. F. Ueber die Missbildungen der Gewächse. Stuttgart, 1814.

most important being those of Schlotterbeck,[4] Engelmann[5] and Moquin-Tandon.[6] Since the middle of the last century numerous smaller papers on teratological subjects have appeared. The earlier data have been collected by Masters[7] and by Penzig,[8] in the former publication the abnormalities being arranged according to kind, in the latter under the various families, genera and species.

The main point of interest in abnormal forms lies not in the mere fact of the existence of the abnormalities nor in the extremes which they may reach, but rather in the light thrown by them upon plant development,[9] and they are therefore entitled to equal consideration with hybridization[10] which, as de Vries[11] has pointed out, permits the analysis of the specific characters and thereby makes possible the study of a single character, since the plant is to be considered merely as an expression of the reaction of elementary units, sometimes occurring singly, at other times in groups.

Among the plant monstrosities which are most frequently observed are fasciations, in which more often the stems, but sometimes other parts of the plant, appear to broaden and assume a flat appearance. Their existence has been known for centuries, for instance the fasciation of *Sedum reflexum* (*S. crispum*), illustrated by Munting[12]

[4] Schlotterbeck, P. J. Schediasma botanicum de monstris plantarum quo analogiam regno vegetabili cum animali intercedentem in producendis iisdem adstruit et figuris illustrat. *Acta Helvetica*, 2: 1, 1816.

[5] Engelmann, G. De Antholysi Prodromus. Frankfurt a. M., 1832.

[6] Moquin-Tandon, A. Éléments de Tératologie Végétale. Paris, 1841.

[7] Masters, M. T. Vegetable Teratology, London, 1869.

[8] Penzig, O. Pflanzen Teratologie. Genua, 1890–1894.

[9] Goebel, K. Bedeutung der Missbildungen für die Theorie der Organbildung. Organographie der Pflanzen, 173, 1898–1901.

[10] Tschermak, E. The Importance of Hybridization in the Study of Descent. Report of the Third International Conference on Genetics. Royal Horticultural Society, 278–284, 1906.

[11] de Vries, Hugo. Intracellulare Pangenesis. Jena, 1889. Sur les unités des charactères spécifiques et leur application a l'étude des hybrides. *Rev. gén. bot.*, 12: 257, 1900.

[12] Munting, A. Waare Oeffeninge der Planten, 1672.

and in numerous species, in fact, in so many species, in so many genera and in so many families, among fungi, among gymnosperms, among monocotyledons and dicotyledons, on herbs, on shrubs and on trees, that the assumption appears justified that fasciation may be expected to make its appearance at some time, in some part, in any species. This is the view held by Sorauer,[13] but de Vries[14] does not make so sweeping a statement.

Fasciations may be propagated vegetatively, for instance, by means of tubers, as in *Oxalis crenata*[15] or through cuttings, as was done at the Missouri Botanical Garden for fasciations of the tomato, *Solanum Lycopersicum*, snap-dragon, *Antirrhinum majus*, hen-and-chickens, *Echeveria glauca* and others. Fasciations may also be transmitted through seed. Among the best known instances is the cockscomb, *Celosia cristata* and its varieties, which, because of this abnormality, is cultivated in gardens. It is a form which, like the cockscomb amaranth, *Amaranthus cristatus*, has been known for centuries to exist, and is always propagated through seed. Recently it has again been shown for Munting's *Sedum reflexum*[16] as previously by de Vries.[17]

The possibility of the transmission of the fasciated character to the offspring, had already been recognized by Godron[18] who, however, says: "Les fasciés sont rarement héréditaires et jamais d'une manière absolue." While the truth of the latter part of the statement has been borne out by subsequent work, in the light of experiments carried on during the last twenty years, and especially those of de Vries,[19] the first part should be amended.

[13] Sorauer, P. Handbuch der Pflanzen-krankheiten, 1^9: 334, 1906. "Die Fähigkeit zur Fasciation ist bei allen Pflanzen voraus zu setzen."

[14] De Vries, Hugo. Die Mutationstheorie, 2: 551. Leipzig, 1901–1903.

[15] 17th Ann. Rep. Missouri Botanical Garden, 147, 1906.

[16] Von Wettstein, R. Die Erblichkeit der Merkmale von Knospenmutationen. Festschrift zu P. Ascherson's Siebzigstem Geburtstage, 509, 1904.

[17] Mutationstheorie, 1: 128.

[18] Godron, A. Mélanges de Tératologie Végétale. *Mém. Soc. d. Sc. Nat. d. Cherbourg,* 16: 97, 1871–1872.

[19] De Vries, Hugo. Over de erfelykheid der fasciatien. Avec un résumé en langue française. *Bot. Jaarb. Dodonæa,* 6: 72, 1894.

We have a right to believe that fasciations, like other monstrosities, with the exception, perhaps, of some cases of virescence,[20] may be inherited, though not by all descendants. Else such varieties could not be offered on the exchange list of the Amsterdam botanic garden as *Aster Tripolium fasciatum, Geranium molle fasciatum, Picris hieracoides fasciata, Veronica longifolia fasciata* along with *Chrysanthemum segetum fistulosum,* in which the ligulate florets have become tubular like the disk flowers, *Dipsacus sylvestris torsus,* which has a twisted stem, *Lychnis vespertina glabra,* which lacks the trichomes on the pod, etc.[21] But it must be remembered that good soil, great care, especially in the earlier stages, plenty of room—in one word, optimum conditions only—give the desired result.

Of far greater interest, at the present time at least, is the consideration of the causes of fasciation and its exact nature. Two kinds of fasciation appear to be possible. The one is caused by the combination, in a plane, of several axes, according to Lopriore.[22] The other mode of fasciation, far more common, and the one which will be considered here, consists of the flattening of the stem through a broadening of its apical cone into a comb, as shown by Nestler,[23] who did his work at the laboratory

[20] De Vries, Hugo. Een epidemie van vergroeningen. Avec un résumé en langue française. *Bot. Jaarb. Dodonæa,* 8: 66. 1896.

In at least one case, that of the green-flowered *Oxalis stricta,* it has been shown that virescence may be transmitted through the seed (18th Ann. Rep. Missouri Botanical Garden, 99, 1907). The third observed, generation of these plants, now (January, 1908) in flower in the greenhouse, still shows the typical character. Now, as formerly, there is no sign of insects to which the cause of the virescence could be attributed.

[21] De Vries, Hugo. Erfelyke monstrositeiten in den ruilhandel der botanische tuinen. Avec un résumé en langue française. *Bot. Jaarb. Dodonæa,* 9: 62, 1897.

[22] Lopriore, G. I caratteri anatomici delli radici nastriforme. Ex. in *Zeitschr. f. Pflanzenkr.,* 14: 226, 1904.

"Solche bandförmige Nebenwurzeln entstehen entweder durch dichtes Aneinanderschlieszen mehrerer senkrecht übereinanderstehenden zylindrischen, oder durch gleichsinnige Verwachsung der Zentralzylinder mehrerer Seitenwurzeln, die sich mit einer gemeinsamen Rinde umgeben."

[23] Nestler, A. Untersuchungen über Fasciationen. *Oester. Bot. Zeitschr.,* 44: 343, 1894.

for plant physiology at Amsterdam under the direction of de Vries. That we are dealing with but a single branch, and not several, though frequently the ribbed appearance of a fasciation gives cause to think otherwise, is well shown by Sorauer [24] in the case of a fasciation of the Norway spruce, *Picea excelsa*. It is demonstrated first of all by the position of the leaves, which are arranged in continuous spirals, and further by the cross sections of the fasciation at different points. They all show the vascular bundles and the pith arranged as a single, continuous mass, and not as a combination of a number of adjacent rings, which would have been the case had the fasciation resulted through the union of various originally distinct branches.

For the sake of convenience in discussion, the causes of malformations in general and fasciation in particular will be considered under four heads: (1) Mechanical action, brought about by the elements, man or other vertebrates; (2) cases where no injury can be traced; (3) the action of fungi; and (4) the action of insects.

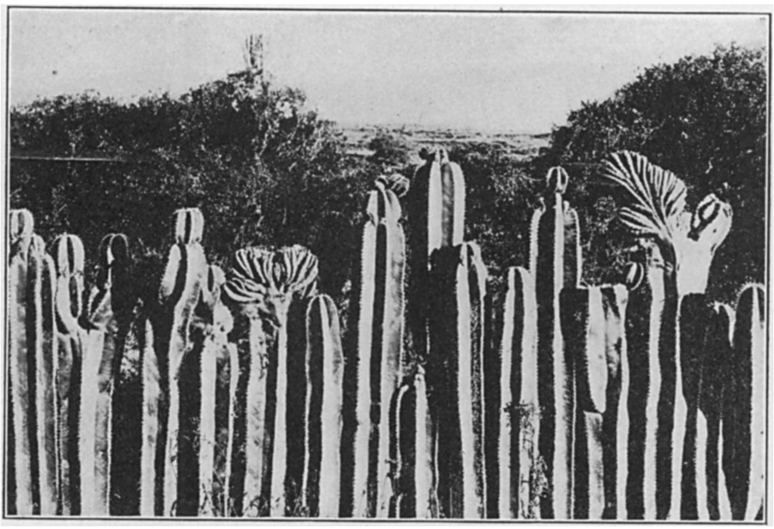
Traumatisms appear, in the majority of cases, to be the inciting causes of the appearance of teratological characters. Numerous instances of this are to be found throughout our literature. Blarighem [25] found that in the case of the pansy, *Viola tricolor* var. *maxima*, it was caused by an accidental crushing of a young shoot. Similarly, he has been able to constatate [26] that in clover fields which had been mowed twice, the number of individuals of red clover, *Trifolium pratense*, bearing 4–5-foliate leaves, was from 12 to 37 per hundred, while in fields which never had been cut, but 5 to 8 such plants were found per thousand. Sainfoin, *Onobrychis sativa*, under the same conditions, produced in its pinnate leaf, leaflets grouped in threes and fours. Plants of the ox-eye daisy, *Leucanthemum*

[24] *Ibid.*, 333.

[25] Blarighem, L. Production par traumatisme d'anomalies florales dont certaines sont héréditaires. *Bull. Mus. d'Hist. Nat.*, 10: 399, 1904.

[26] Blarighem, L. Anomalies héréditaires provoqués par les traumatismes. *Compt. Rend. Acad. Sc.*, 140: 378, 1905.

vulgare (*Chrysanthemum leucanthemum*), of which the stems had been cut, bore heads on which at least a part of the ligulate flowers had been changed to tubular flowers, as well as heads, which in the axils of the bracts, bore secondary ligulate florets. Life[27] mentions the case of a plant of *Ambrosia artemisiæfolia* which, having been run over by a wagon and badly injured in consequence, bore both staminate and pistillate flowers in an abnormal condition. A hedge composed of plants of *Cereus margi-*



"ROSA DE ORGANO"—*Cereus marginatus.*

natus, which, under the name Organo, is largely used as a hedge plant in Mexico, which was partly injured, probably because of securing cuttings for planting, shows numerous fasciations.[28] Klebs[29] mentions the observations of Krasan, who noted fasciation caused by a loss of leaves through the action of june bugs or spring frosts.

[27] Life, A. C. An Abnormal Ambrosia. *Bot. Gaz.,* 38: 383, 1904.

[28] A photograph, by Professor Frederick Starr (reproduced here), illustrating a large portion of a hedge thus fasciated, and a cast of one of the branches, are in the herbarium of the Missouri Botanical Garden. See also *Trans. Acad. Sc. St. Louis,* 9: xx, 1899.

[29] Klebs, G. Ueber künstliche Metamorphosen. *Abh. naturf. Gesell. Halle,* 25: 134, 1903–1906.

It is but natural to suppose that if accidental mechanical injury can produce abnormalities, the same can be produced experimentally through similar action. Again, numerous cases are on record. The first instance known is probably the experiment of Sachs,[30] who, amputating the main stem of bean seedlings just above the cotyledons, was able to bring about fasciation of the shoots produced from the buds in the axils of the cotyledons. A fasciation of *Ibervillea sonoræ* at the New York Botanical Garden, referred to in *Torreya*,[31] is understood to have been artificially caused by intentional slight injury of the growing tip. Blarighem[32] was able to cause fasciation of shoots of *Viola tricolor* var. *maxima* by crushing the young stems. Lopriore,[33] incited by the experiments of Sachs, cut the root tips of seedlings of *Vicia Faba* and obtained fasciated roots in a large number of cases, as well as malformations of other parts of the plant.

But apparently a fasciation is not necessarily a consequence of mutilation. Goebel[34] mentions fasciations in suckers and watersprouts. These are so common that they probably have come within every one's notice. Fasciations also frequently occur in plants the seedlings of which were abnormal in having a larger number of cotyledons than usual.[35] It has been shown[36] that under proper conditions of moisture and food, plants will frequently fasciate, though adjacent plants may remain normal. Such cases have generally been ascribed to peculiar conditions of nutrition.

[30] Sachs, J. Physiologische Versuche über die Keimung der Schminkbohne (*Phaseolus multiflorus*). *Sitzungsber. d. k. k. Akad. d. Wiss. in Wien*, 37: 57, 1859.

[31] Knox, Alice A. Fasciations in *Drosera, Ibervillea,* and *Cecropia. Torreya*, 7^5: 102.

[32] *Loc. cit.*

[33] Lopriore, G. Verbänderung infolge des Köpfens. *Ber. d. d. Bot. Ges.*, 22: 304, 1904.

[34] Goebel, K. Organographie der Pflanzen, 164, 1898–1901.

[35] De Vries, Hugo. Eine Methode, Zwangsdrehungen aufzusuchen. *Ber. d. d. Bot. Ges.*, 12^2: 25, 1894.

[36] 17th Ann. Rep. Missouri Botanical Garden, 147, 1906.

That parasitic fungi are able to produce an alteration of form in plants has long been known. One of the most familiar abnormal growths from such a cause is what is commonly termed a witch's broom, so often observed on evergreens. It is due to the action of species of Exoascus and Æcidum, which induce the formation of a large number of adventitious buds within a comparatively short area of the stem or branch, which give rise to a corresponding number of short, thickened twigs. In the silver fir, *Abies pectinata,* witches brooms are produced by *Æcidium elatinum.*[37] Frequently galls are produced by fungi, affecting either roots, stems or leaves, but no cases are on record where a fungus was shown to be the cause of fasciation. This is different where gall-insects are concerned. Here some cases have been traced directly to gall-insects[38] as the cause.

Galls, otherwise known as cecidia, and distinguished according to their origin into zoo- and phytocecidia, are among the most interesting of the abnormal forms which from time to time make their appearance as excrescences of widely varying shape, color and structure. Recognized by Pliny, some were even in those early days used in medicine because of their astringent properties. To-day, a number of them, especially some occurring on certain species of Quercus, Pistacia, Rhus and Tamarix, are of economic value[39] on account of their tannin content, and a gall produced by *Cynips tinctoria* upon branches of the dyer's oak, *Quercus lusitanica* (*Q. infectoria*), found in the countries bordering the Mediterranean and in the Orient, is official in the U. S. Pharmacopœia. Members of widely different orders of insects may be the cause of the

[37] Kerner, A., and Oliver, F. W. The Natural History of Plants, 2: 527, London, 1894–5.

[38] Though gall insects only are discussed here it does not follow that larvæ of other insects may not be the cause of fasciation. The relation between fasciation in species of Œnothera and the larvæ of a small moth, Mompha, is discussed in a very interesting, well illustrated paper by Knox, *The Plant World,* 10^7: 145.

[39] Wiesner, J. Die Rohstoffe des Pflanzenreiches, 1: 674, Leipzig, 1900.

production of a gall. Among the Arachnida, many of the mites do so, some species causing serious injuries; for instance, the pear leaf blister mite, *Eriophyes pyri,* and *E. oleivorus,* which causes the so-called "russet" oranges.[40]

To the Hemiptera, of which the plant-lice, Aphididæ, are best known, belongs the dreaded *Phylloxera vastatrix,* which some thirty years ago so seriously crippled the vineyards of France. It forms galls on both the leaves and the roots. The Diptera, to one of the families of which our common house fly belongs, yield the Cecidomyidæ. One of these very small insects is the cause of the goldenrod rose. Neither the Lepidoptera nor the Coleoptera have many members which are the cause of gall formation. This is different as far as the Hymenoptera are concerned. A large number of species, especially those belonging to the Cynipidæ, are the cause of the formation of some of the largest, most strikingly colored galls, of which those occurring on oaks (Cynips) and roses (Rhodites) are probably the most familiar.

In some cases the causation of fasciations has been ascribed to gall-forming animals. Kerner[41] speaks of the fasciations of the ash, *Fraxinus excelsior* and *F. ornus,* caused by a mite, Phytoptus (Eriophyes). De Vries[42] mentions a stem of *Hieracium vulgatum* attacked by *Aulax Hieracii* which was normal below the gall, but above it was fasciated. Not only fasciations, but numerous other monstrosities have been brought into relation with gall insects. Treub[43] observed virescence caused by the same insect. Nalepa[44] mentions *Phytoptus anthocoptes* as the cause of virescence of flowers, thickening of the capita and frequent secondary formation of capitula on *Cirsium*

[40] Cook, M. T. Insect galls of Indiana. Indiana Dep. of Geol. and Nat. Res., 29th Annual Report, 801, 1904.

[41] *Ibid.,* 2: 549.

[42] Mutationstheorie, 1: 291.

[43] Treub, M. Notice sur l'aigrette des Composées a propos d'une monstruosité de l'*Hieracium umbellatum. Arch. Neérl. d. sc. phys. et nat.,* 8: 1.

[44] Nalepa, A. Neue Arten der Gattung *Phytoptus* und *Cecidophyes. Denkschr. d. k. Acad. d. Wiss.,* 59: 525, 1892.

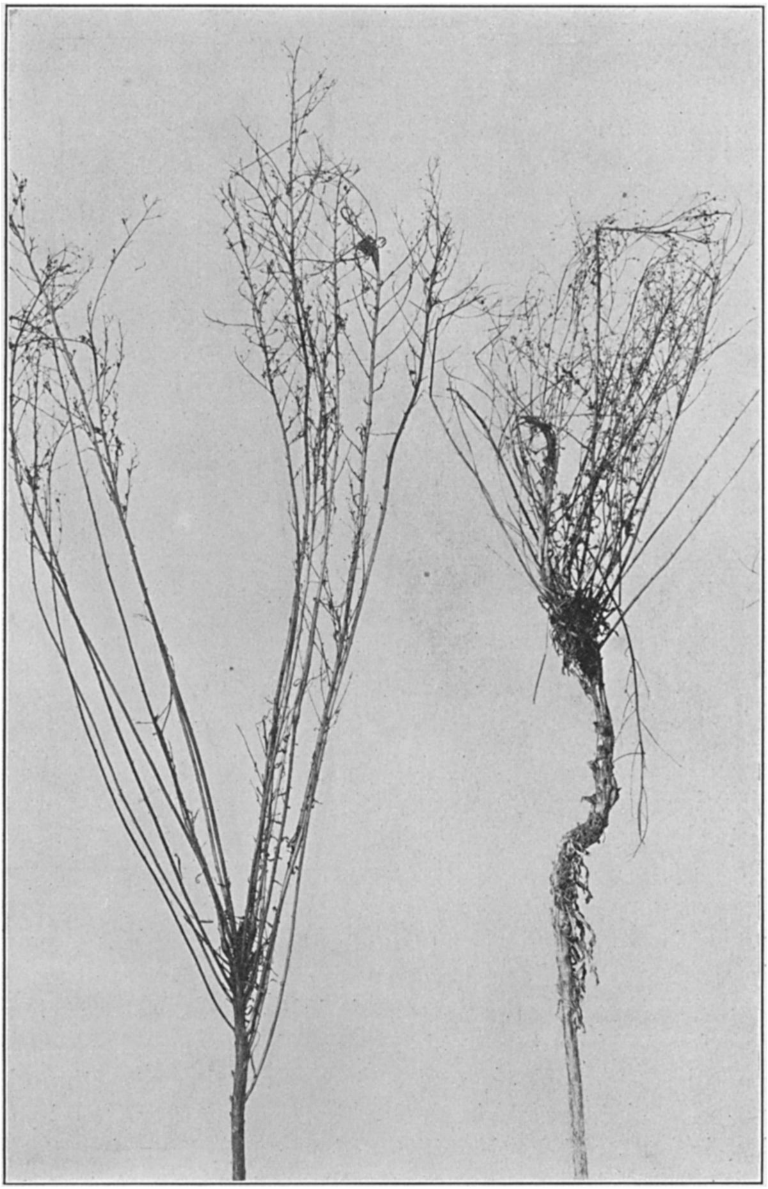
arvense, P. cladophthirus as the cause of gray-hirsute malformations of the shoots of *Solanum Dulcamara,* and *P. genistæ* as the cause of malformations of the tips of the shoots and abnormal hirsuteness of the buds of *Genista pilosa* and *Sarothamnus scoparius.* The virescence of the inflorescence of different species of Arabis, due to Aphides, was studied by Peyritsch.[45] De Vries[46] ascribes an epidemic of virescence among the plants in his experimental garden to an original infection caused by Phytoptus, though he was unable to demonstrate the presence of the mite. Finally Molliard[47] investigated the influence of fungi and insects causing floral cecidia upon the reproductive cells.

From the above it will be gathered that there exists a very definite relation between malformation in plants and gall-insects. For this reason a large number of strikingly abnormal plants of the horse-weed, *Erigeron canadensis,* growing within a narrowly circumscribed area in the immediate vicinity of St. Louis, Mo., attracted immediate attention and awakened considerable interest. Being found in January, nothing but the dried parts remained, which made observation easier. All of the plants were abnormal. Among them two distinct types could be distinguished. These types agreed in one particular. From the ground to a place 2½–3 feet above the soil, the plants were normal. It was above this point that the abnormality presented itself. In the first type, when the plant had reached a height of from 2½–3 feet above the ground it had evidently experienced a check. The main stem terminated here in a very much dried-up shoot but an inch or less in length, showing that it never had an opportunity to perfect its woody tissue. Just below this point numerous small side shoots occurred. These side

[45] Peyritsch, J. Zur Ætiologie der Chloranthien einiger Arabis Arten. *Jahr. f. Wiss. Bot.,* 13: 1, 1882.

[46] De Vries, Hugo. Een epidemie van vergroeningen. *Bot. Jaarb. Dodonæa,* 8: 66, 1896.

[47] Molliard, M. Recherches sur les Cécidies Florales. *Ann. d. Sc. nat. bot.,* 8. Sér., 1: 67, 1895.



Cecidomyian Deformities of *Erigeron*.

shoots had an average length of from $1\frac{1}{2}$–2 feet, and, issuing within a space of 3 inches from the atrophied tip, gave the dried plant a peculiar broom-like appearance. Upon them, usually immediately at the base, frequently within 2 or 3 inches from the base and sometimes at a distance of one foot from the base of the side shoot, occurred elongated swellings, from $\frac{1}{2}$–$\frac{3}{4}$ inch long and increasing the thickness of the stem to three times its normal size. These also occurred on stems of the second type, which bore fasciations. Each of the swellings contained a single orange-colored larva, which Dr. M. T. Cook kindly determined as that of *Cecidomyia origeroni*. The species of Diptera, to which *Cecidomyia* belongs, lay their eggs on the surface of the plant, and the larvæ, after hatching, penetrate the tissues. In this they agree with the Arachnida and Hemiptera. The Hymenoptera puncture the tissues and deposit their eggs within the plant tissues. It has long been a question in exactly what manner the abnormal growth due to gall insects is caused. Some ascribe it to mere mechanical irritation on the part of the larvæ, others believe it to be due to a chemical stimulus emanating either from the parent insect, which, at least in some instances, deposits, along with the egg, a certain chemical substance, or from the young larvæ only.[48] The latter happens in the case of the gall caused by *Cecidomyia Poæ* upon *Poa nemoralis*,[49] and which brings about the formation of roots in places where normally they are never found. But when *Nematus Capreæ* makes a wound in the leaf tissue for the purpose of depositing an egg, a gall develops, whether an egg is laid or not. Even when the former has taken place, though the egg be subsequently destroyed, the gall develops just the same, though never attaining full size. For that matter, mere mechanical irritation, *i. e.*, the killing of one or a few cells at the

[48] Beyerinck, M. W. Beobachtungen über die ersten Entwickelungsphasen einiger Cynipidengallen, 177. *Veröffentlicht d. d. k. Acad. d. Wiss. zu Amsterdam*, 1882.

[49] Beyerinck, M. W. Die Galle von *Cecidomyia Poæ* an *Poa nemoralis*. *Bot. Zeit.*, 43[20]: 304, 1885.

side of an organ, may result in the malformation of the adult organ, and, according to Ward,[50] may be proved experimentally by aid of a needle. But the assumption of a mere mechanical injury is not sufficient to account for the presence and shape of galls. The same insect, on different hosts, may produce different galls. Again, two distinct species of gall-insects produce very different galls on the same plant or even on the same leaf. Further, experiments to bring about artificially the formation of galls through the injection of different chemicals, have thus far proved unsuccessful.[51]

Among plants of *Erigeron canadensis* fasciation appears to be quite common.[52] When, however, among the plants of this fleabane infected by the Cecidomyia a large number, at least 10 per cent., were found to be fasciated, it was but natural to attempt to bring the two phenomena into relation. In some of these fasciated plants the fasciation begins within two feet of the ground; in others, and these form the majority, the fasciation began from $2\frac{1}{2}$–3 feet above the soil surface and above the point where the galls occurred on the main stem. But while the non-fasciated plants showed a large number of long side shoots, developed at the expense of the main stem, the fasciated plants did not differ materially from normal plants in this regard. A large number of short side shoots bearing flowers were produced on a fasciated main stem. The most plausible explanation is that in the former case the growth of the main stem was inhibited absolutely and that all the strength went to form side shoots, while in the latter case the growing point was not affected sufficiently to dry up. Instead, growth was stimulated. Whether the action of the galls was of a mechanical or chemical nature, though of great interest in other cases, is of comparatively little importance here, and for the following reasons:

[50] Ward, H. Marshall. Disease in Plants, 131, London, 1901.

[51] Küstenmacher, M. Beiträge zur Kenntnis der Gallenbildungen mit Berücksichtigung des Gerbstoffes. *Jahrb. f. wiss. Bot.*, 26: 82, 1894.

[52] Penzig, *loc. cit.*

It has been conceded generally that fasciations are due to changed conditions of nutrition. Nestler, de Vries, Goebel, Sorauer and many others agree that they are induced either through an increase of nutrition of the entire plant or of that of certain shoots through the removal of others. In other words, it is due to a change of the chemical and physical conditions within the cell. The influence of chemical substances upon plant and animal cells has been widely studied. Among the best known are the experiments of Johannsen[53] in which lilac bushes and other flowering shrubs, of which we see the branches in the florist's windows in early spring, under proper conditions of moisture and temperature, were for a certain length of time exposed to the action of ether or chloroform, after which they bloomed several months earlier than normally would have been the case. Loeb's experiments on the cleavage of unfertilized eggs of the sea urchin, after having been treated with magnesium chloride, are too well known to make it necessary to go into detail. The same thing is true for his studies on the influence of the lack of oxygen and resultant modification in the cleavage of eggs of Echinodermata. Migula's experiments on the influence of dilute acid solutions on algal cells, Richards' work on the development of fungi under the influence of chemical stimuli, and especially the work of Sabline on the influence of external agents on the roots of *Vicia Faba* show that external influences may bring about profound nuclear changes. Still better, this is brought out by the injection experiments of MacDougal,[54] who was able to produce new species through the injection of dilute salt solutions into the capsules of evening primroses. And in the case of hyphæ of many of the Chytridiaceæ, which bring about abnormal cell divisions in the tissues of the host plant, the protoplasm of

[53] Johannsen, W. Das Aetherverfahren beim Frühtreiben, 2e Aufl., Jena, 1907.

[54] MacDougal, D. T., A. C. Vail and G. H. Shull. Mutations, Variations and Relationships of Œnotheras. Carnegie Institution of Washington Publication, No. 81, 1907.

the parasite never comes in direct contact with that of the host. Yet their influence extends to cells at some distance from the point of infection. Even where the hyphæ do not actually enter the cell, a stimulation to abnormal growth often takes place. Experimentally mere mechanical action has brought about profound changes. Molliard was able to induce the formation of double flowers through mechanical irritation.

That the action of galls is of a chemical nature is well shown by Molliard,[55] who describes and figures profound nuclear changes preceding the hypertrophy of *Geranium sanguineum* attacked by *Phytoptus Geranii.*

If fasciations, which are due directly to chemical changes within the cells, may be inherited, then why not galls? But acorns from an oak covered by galls produce normal plants only. Still, one might expect galls to be inherited in preference to fasciations. Does not de Vries[56] say: "It is clear that the beautiful, highly complex and judicious structure of the cynipid galls, with their food tissue, layers of stone cells, and the tannin-bearing, loose, outer parenchyma, in thickness adapted to the egg apparatus of the parasites and inquilinæ, can not be brought about by a mere mechanical stimulus." Kerner goes so far as to say that it is within the limits of possibility that the first double flowers were caused by some gall.

There is no direct evidence of the inheritance of abnormalities brought about through the influence of gall insects or their larvæ. Fasciation, however, from whatever cause, may be inherited by a greater or less percentage of the offspring. We may then assume there must be a predisposition to the formation of fasciation in all plants which up to this time have been known to produce them. Probably this disposition is present in all other plants. The assumption of a mere excess of nutrition is not

[55] Molliard, M. Hypertrophie pathologique des cellules végétales. *Rev. gén. bot.*, 9^{98}: 33, 1897.

[56] Mutationstheorie, 1: 290.

sufficient to explain the inheritance of the character. It is necessary to assume a corresponding and very definite change in the bearers of the hereditary characters. Just how these bearers are constituted or what name is given them is entirely immaterial. It is probable that they are of an exceedingly complex nature. For purposes of illustration they may well be compared with the molecules of organic chemistry, or better still, as has already been done so felicitously, to many-sided prisms, which a very slight jar causes to assume a different position and which finds a corresponding external expression. Under predisposition to fasciation or the latency of the fasciated character should perhaps be understood a tendency on the part of the cell contents, and more particularly the chromatin, to undergo a certain definite change, retained during cell division, of either a chemical or physical nature, under certain conditions brought about by differences in nutrition. The change which causes fasciation is one of the easiest brought about, and hence fasciation is one of the abnormal characters most frequently met with. Though a mere theory, its general truth is supported by a number of instances. Mutations frequently repeat themselves. The identical sports originating from stock obtained from widely different sources and where the probability of a common origin in the remote past may safely be questioned, speak for themselves. The finding in two distinct places in Europe of plants of *Capsella heegeri* Solms, which differs from *C. bursa-pastoris* mainly in the shape of its capsules, is another instance. Mutations in a species are always the same, whatever their direction. They may be widely separated in time and space, but whenever they appear they are identical.

It has been said that fasciations are inherited because the seeds collected for purposes of propagation always were obtained from the abnormal stems. This appears to have happened in the majority of cases. Since, however, we never can know whether a fasciation is inherited

or makes its appearance for the first time,[57] numerous experiments should be undertaken with a view of eliminating "chance" through large numbers. Whether the seed of a bean in which a fasciated root has been produced artificially, gives rise to a fasciated plant, is an experiment worth trying. Likewise, it is an open question whether the seed borne on normal stems of a pansy in the main stem of which fasciation has been induced through crushing, will give rise to fasciated individuals. The spores of the Boston fern, *Nephrolepis exaltata bostoniensis,* give rise to plants the majority of which exhibit the peculiar cristate leaves. Yet here and there on the fronds sometimes will be found non-cristate leaflets. Will the spores borne on the latter give rise to the cristate form? These are experiments which any one with a little space and time at his command and a penchant for gardening, can readily undertake. To such, no small hope of reward is held out in a recent paper by Blarighem,[58] who, as a result of mutilation, obtained entirely new and constant varieties.

[57] This is true even when it appears as a bud variation, for the character may have been latent in the parent plant. One can, therefore, not speak, in such a case, of an "acquired" character in the strictest sense.

[58] Blarighem, L. Action des traumatismes sur la variation et l'héridité. *Compt. Rend. hebd. d. Séanc. et Mém. de la Soc. de Biol.,* 57^2: 456, 1905.